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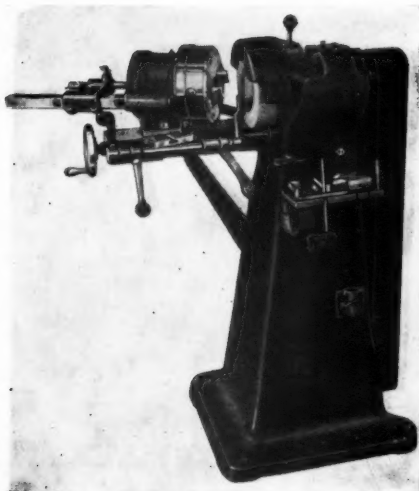
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SCREW THREADS

*Paper presented to the Institution, Western Section, by
J. T. Kenworthy, M.I.P.E.*

THERE is no other engineering element in such common use as the screw thread, in one form or another. We come in contact with it at all times of the day, and yet how little do we realise this. The origin of the screw thread dates back to 236 B.C. and is credited to Archimedes. It is recorded that the Romans made good use of this invention by applying it to their wine presses and city gates. Some good examples of screws which have been in use for many generations are to be found fitted to cider presses in many West country farms. History records the use of instruments of torture such as thumbkins or thumbscrews in which the screw thread was employed. Conjecture is often made as to the manner in which the Pyramids were built and by what means the weighty material was raised to the required height. The assumption is that this was accomplished by the use of inclined planes. Here we have the screw thread in its embryo stage, for what else is the screw thread but an inclined plane generated round a cylinder?

Screw threads have a great many uses but these can generally be covered by three main headings: (1) For securing parts together, e.g., the ordinary bolt and nut. (2) For propelling moving parts, e.g., the lead screw in a lathe propels the saddle. (3) Adjustment and measuring, e.g., the screw in a micrometer.

The types of screws in use are legion. In this country we have the Whitworth thread with its standard thread and fine thread for general use (B.S.W. and B.S.F.), British Association (B.A.), Brass Thread, Pipe Thread (B.S.P.), Cycle Engineers Institute Standard Thread, Optical Instrument Thread, Square Thread, Buttress Thread, Acme Thread, and many others. Then we have the standard threads of other countries, chief of which are the *Système International Metric Thread* (French), *German Metric and Lowenherz Thread* (German), and *American National Thread* (formerly Sellers).

For the purpose of this paper I propose to deal principally with the *British Standard Whitworth Thread*. This was proposed by Sir Joseph Whitworth, and a full table of sizes published in 1841. Apart from the deletion of some of the smaller sizes which have been superseded by B.A. sizes, and the omission of some intermediate sizes, this list has stood for nearly one hundred years. It is true also

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that the B.S.F. version of this thread has replaced the B.S.W. where extra strength is required or where parts are subject to shock or vibration, but the nomenclature of the thread itself has not changed. This is somewhat surprising, as the thread is a difficult one to produce accurately, there being seven elements which have to be controlled. These are : (1) Pitch ; (2) effective diameter ; (3) outside diameter ; (4) core diameter ; (5) radius of root ; (6) radius

THREAD FORMS

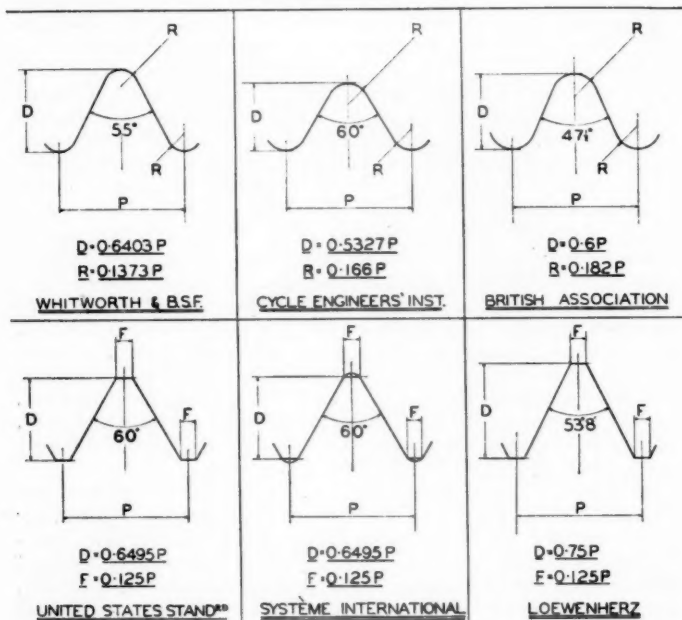


Fig. 1.

of crest ; and (7) angle of flank. The three most important of these elements are (1), (2), and (7).

In the American National Thread the radii at the root and crest are omitted and substituted by flats and the included angle of the flanks is 60°. The Lowenherz Thread also has flats instead of radii at root and crest, but the included angle of the flanks is 53.8°. The Système International Metric Thread has an inclined angle of flanks of 60°, the top of the thread is flat and the root has an optional radius within specified limits.

The science controlling the production and inspection of threads has developed very rapidly in recent years. During the present century, it was common practice to strike out a thread with a hand tool and finish with a chaser. With the advent of lead screws on lathes, the striking out of the thread was done by a tool fixed in the saddle and propelled at the correct speed in relation to the rotation of the work and then finished with special single point tools or if extreme accuracy was not required, by chasing.

The advent of the diehead allowed comparatively rapid production, but doubtful accuracy. The early forms of dieheads employing solid and adjustable reversing dies were never very satisfactory. They had to be reversed off the work, and the finish of the thread suffered in consequence. Another difficulty encountered was the inaccuracy due to the distortion in heat treatment and initial inaccuracies due to method of manufacture of the dies. The Self-opening Diehead solved some of these difficulties. The speed of production was increased. The cutting rake was controlled in a better manner, more correct cutting relief was obtained, and the type of die lent itself to more accurate production.

This type of diehead—and I have in mind as an example the Coventry Self-opening Diehead as produced by Messrs. Alfred Herbert—has been improved enormously in recent years. The Zonic Lapped Dies are produced to a very high degree of accuracy. The lapping enables the die to be produced with smooth flanks and correct tooth form, accurate in pitch, with correct rake and relief, and these essentials are maintained during the grinding of the dies in special fixtures. It is claimed that with this type of diehead, threads can be cut to B.S.I. Close Tolerances.

Modern development in the production of screw threads has brought into use two other reliable methods of production. These are thread milling and thread grinding. Thread milling of threads of the B.S.W. and B.S.F. types is carried out by means of a cutter of a series of annular threads which rotates at a normal cutting speed. The cutter is fed into the work whilst the work is rotating and the thread is completed after one complete revolution of the work spindle. The shape of the thread form on the cutter is slightly modified from the standard form to compensate for the helix angle of the thread. There are many other forms of thread milling, such as the production of Acme and square threads with a single cutter and the cutting of worm threads. Multiple start worm threads are also frequently generated on a hobbing machine. Thread grinding has been practised for some considerable time but it is only latterly with the advent of the multiple wheel that it has become a recognised method for the commercial production of components. In the early days of thread grinding, a single wheel was used and the difficulty encountered was that of dressing the wheel and maintain-

ing its shape during grinding. The American thread with its flat crest and root lent itself to grinding more readily than the Whitworth thread with its rounded root and crest.

In the early days the wheels were dressed with a diamond traversed across each side of the wheel at the correct angle, but no means were available for forming the radii for the crests and roots. Eventually a form of crusher was used which generated a radius in the face of the wheel and the grinding of the crests was carried out separately from the grinding of the flanks. About 1930 the dressing of the wheel was improved by using a pantograph arrangement in conjunction with a master thread form, twenty-five times full size.

A stylus which was also 25 times the size of the diamond, contacted with the master form. Shortly afterwards the multi-ribbed wheel came into being. The wheel when dressed comprises a series of annular threads which can be generated to the correct shape by means of a master former. A stylus is in contact with the former and this controls the movement of the diamond, which is used to generate the thread form on the wheel.

A further development in the dressing of the wheels was the introduction of the crusher in a new form. The new crushers consisted of annular rings of correctly formed thread section. After roughing the wheel to shape with the diamond from the master former, the crusher was applied to the wheel with a light pressure and the wheel turned slowly by hand. This gave a true shape to the wheel and improved its cutting texture. There are many types of crushers now being used, but the principle of their application is the same.

A considerable development has taken place in the type of grinding wheel used on multi-rib grinding. Grits varying from 90 to 220 are now in use giving satisfactory results, and have made this method of grinding possible. An important feature of this method of grinding is the type of cutting lubricant used. With an unsatisfactory coolant burning is evident and frequently grinding cracks are experienced. This method of grinding now gives results which are considered to be satisfactory for the grinding of gauges although for this latter purpose grinding with the single wheel is still used to a great extent. Another method of finishing gauge threads is by lapping. This is rather a slow and costly process and is gradually being superseded by grinding.

A method of producing screw threads on bolts which gives satisfactory results for commercial use is that of cold rolling. Much research work has been carried out in connection with this process and it is believed extremely satisfactory results can now be obtained.

The production of female threads is a more difficult proposition than that of producing the male thread. For small holes, there appears to be no alternative to the tap. In this case the size of the

SCREW THREADS

thread, as well as the form is controlled by the tap. It is now possible to obtain ground thread taps manufactured to a great degree of accuracy. These are guaranteed to be correct to within 0.0002 in. in a length of 1 in. in regard to pitch and the effective diameter is within $+0.0003$ in. to -0.0001 in. of the specified size. To suit special requirements and by selection even greater accuracy can be obtained. Further advantages of the ground tap are that the threads are produced to a correct form and good finish, and the threads are relieved, giving a much better cutting action. The relief on these taps is usually such that although they will produce holes within specified limits when new, and although the threads are relieved, they retain a cutting size within their specified limits during the life of the tap. Unground taps are prone to suffer from many inaccuracies, such as pitch error, lack of relief, inefficient cutting angles, and distortion. This lack of relief often causes torn threads and broken taps. In addition, an unground tap is often cutting

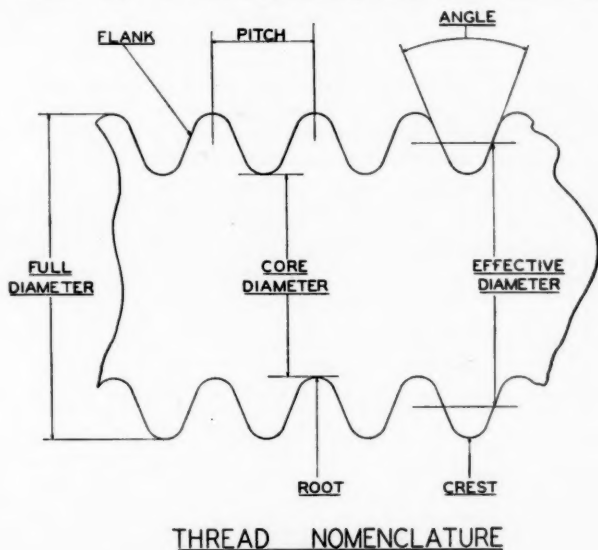


Fig. 2.

undersize whilst there is still a considerable amount of life in the tap. For larger size holes thread milling lends itself admirably, and this method of production is rapidly developing.

Let us now examine more closely what we have been trying to produce.

Effective Diameter of a Screw.—The effective diameter of a perfect screw having a single thread is the length of a line drawn through the axis and at right angles to it, measured between the points where the line cuts the flanks of the thread.

Core Diameter.—The core diameter is twice the minimum radius of a screw, measured at right angles to the axis.

Full Diameter.—The full diameter is twice the maximum radius of a screw, measured at right angles to the axis.

Crest.—The crest is the prominent part of the thread, whether of the male screw or of the female screw.

Root.—The root is the bottom of the groove of the thread, whether of the male screw or of the female screw.

Flank of Thread.—The flank of the thread is the straight part of the thread which connects the crests and roots.

Angle of Thread.—The angle of the thread is the angle between the flanks, measured in the axial plane.

Pitch.—The pitch is the distance measured along a line parallel to the axis of the screw between the point where it cuts any thread of the screw and the point at which it next meets the corresponding part of the same thread. The reciprocal of the pitch equals the number of turns per inch. The three main elements controlling the amount of bearing on the flanks are accuracy of pitch, correct angle of flanks, and to a lesser extent, effective diameter.

The question of tolerances on screw threads has not received the attention it merits. The British Standards Institution is usually looked to for a suitable choice of tolerances but those at present existing are inadequate for commercial use. The existing standards are known as "close limits" and "standard limits." The "close limits" are too fine for normal production and a range of wider tolerances than "standard limits" is required. This gap has been adequately met by Messrs. Alfred Herbert, who have established five grades of tolerances S.F.M.C. and R. The Air Ministry have a standard of tolerances to which work can be produced to their requirements.

The B.S.I. are now considering the revision of their standards and are proposing to include a wider tolerance in addition to the two already existing and also propose to modify the existing ones. The B.S.I. specification shows a gap of 0.002 in. between the top limit of the male thread and the bottom limit of the female thread and in this respect Messrs. Alfred Herbert have established a gap of 0.0005 in. Experience has shown that there is no necessity for this gap and it is expected that it will be omitted in the revised B.S.I. standards.

It is the practice of a number of firms to use truncated threads, i.e., threads from which the crests have been removed. It is believed that the B.S.I. committee are contemplating recognition of this practice where stress is not an important factor, and in that event,

SCREW THREADS

would specify a suitable standard. It is also understood that the length of bearing will have an effect on the tolerance.

It is not so long ago that threads were inspected by means of full form ring and plug gauges and the acceptance of such threads determined by the feel of the gauge. With the number of elements involved, it will be readily understood that a thread may fit on the core or root diameter, and will be outside the limits in regard to other elements. Many other combinations of errors may exist in which a thread would be accepted by a full form gauge and yet be well outside the required tolerances.

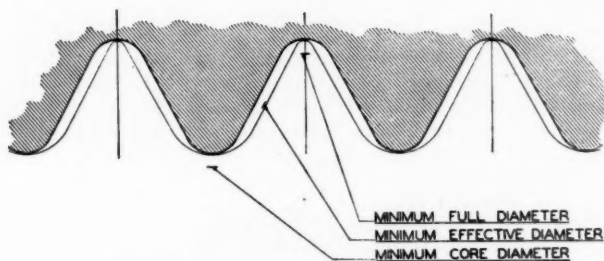


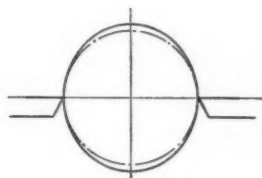
Fig. 3.—Thin thread (tight fit in ring gauge).

It will be readily understood that if each element had to be separately inspected, it would become a very tedious operation. The principle now generally adopted was made possible by the advent of the caliper gauge. The principle involved by this system is to allow the work to pass between two anvils, representing sections of a full form gauge to the maximum tolerance and for the work not to pass between two anvils representing one complete thread which has been truncated and recessed so that only the flanks remain and set to the low effective diameter tolerance.

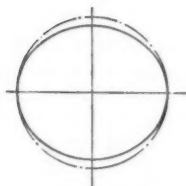
The form of the anvils is made as correct as possible to the theoretical form, the actual amount of variation being specified by the N.P.L. Gauges embodying this method of check are also in use employing rollers. One such type employs rollers which are in effect screw gauges of opposite hand, but of the same size and pitch. One roller is fixed laterally but allowed to rotate and the opposite roller is allowed to float and rotate against a light spring. This method restricts the use of the gauge to a predetermined diameter. Another gauge of this type embodies rollers consisting of a series of annular rings. The principle of construction is similar to that of the previous gauge. The annular rings however are not to the true shape of the thread, suitable correction being made to compensate for the helix angle. This type of gauge can be used for varying diameters.

The full form ring gauge is also in use and when used in conjunction with a "No Go" ring gauge is quite satisfactory. The wear on such a gauge, however, is such that its life is very short, and frequent replacements are necessary. The Wickman and Roller type of gauges can be adjusted to suit any tolerance and the Wickman anvils can be re-ground and re-set giving a long life to the gauge.

It is not intended to consider at length the relative merits of the various types of gauges beyond illustrating one condition in which each type of gauge will accept work outside the required tolerances.



CALIPER TYPE GAUGE.
(ACCEPTS OVAL AND OVERSIZE)



RING GAUGE.
(ACCEPTS OVAL AND UNDERSIZE)

Fig. 4.

Figure 4 shows how work which is oval can be accepted by the caliper type of gauge although oversize in one plane, whilst the full form ring gauge will accept parts which are undersize in one plane. By making a second check on all components at an angle of 90° to the first with the caliper type of gauge such an error should not occur. The real safeguard is the use of the caliper type gauge and full form ring gauge in combination. This type of error is fortunately rare with modern methods of production and need not be considered very seriously. The caliper type of gauge is readily set or adjusted to the

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desired tolerances by means of setting plugs. These are manufactured to very close tolerances as specified by the N.P.L. and for both the "Go" and "No Go" anvils, the plug gauge is truncated and the root recessed leaving only a proportion of the flanks. It will be understood that the production of threads by normal commercial methods will vary from the theoretically correct form and for each error in pitch or variation in angle of flank it will be necessary to reduce the simple effective diameter to a dimension somewhat smaller than nominal size. In this condition the full form anvils of the gauge will accept the component. It is then necessary to ensure that the simple effective diameter of thread has not been reduced below the bottom limit, and this is checked by the "No Go" anvil.

From this information, it will be seen that the working tolerance is somewhat less than the theoretical tolerance, and will vary according to the method of manufacture. As an illustration, let us consider the production of a $\frac{3}{8}$ in.—20T B.S.F. thread by means of a die-head to B.S.I. standard tolerances which shows an effective diameter

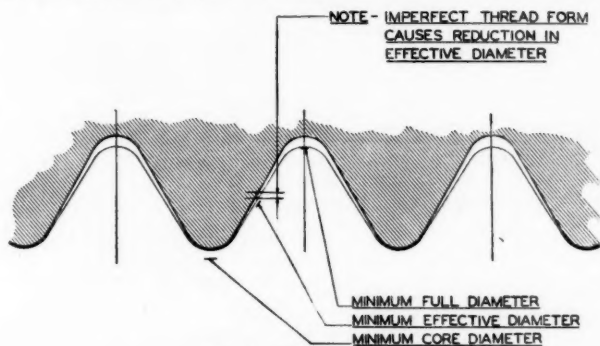


Fig. 5.—Angle too large.

tolerance of 0.0045 in. It will generally be found that when the dies are set so that a thread is produced that will just enter a full form gauge or be accepted by the "Go" anvils of caliper gauge, then the simple effective diameter has been reduced by about 0.002 in.

As the "No Go" gauge checks only the simple effective diameter, the working tolerance is reduced to the difference between 0.0045 in. and 0.002 in., i.e., 0.0025 in. This is a feature which is not generally recognised and it is commonly assumed that the working tolerance and the nominal effective tolerance are synonymous.

The production of threads by grinding gives a much more accurate shape and pitch so that there is a greater proportion of working tolerance or alternatively much closer tolerances can be worked to. The method usually adopted for inspection of threaded holes is by

means of a full form plug gauge to the minimum tolerances as a "Go" and a short gauge with the crests removed and roots recessed to maximum effective diameter as a "No Go" gauge.

The following illustrations show some characteristics which frequently exist either alone or in combination in threads produced by normal commercial methods.

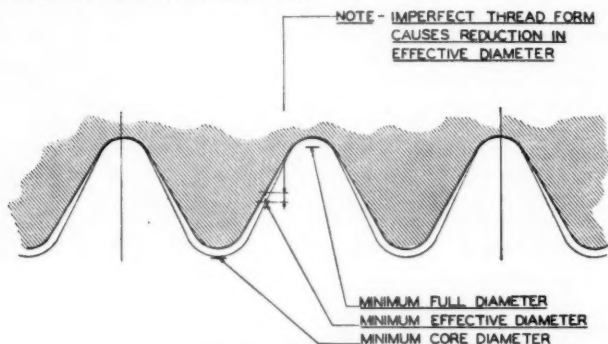


Fig. 6.—Angle too small.

Figure 5 shows a thread with the angle too large. It will be noted that contact with the flank of the gauge is restricted to the region of the root and is virtually point contact.

The next example, Fig. 6, shows the reverse condition, i.e., with

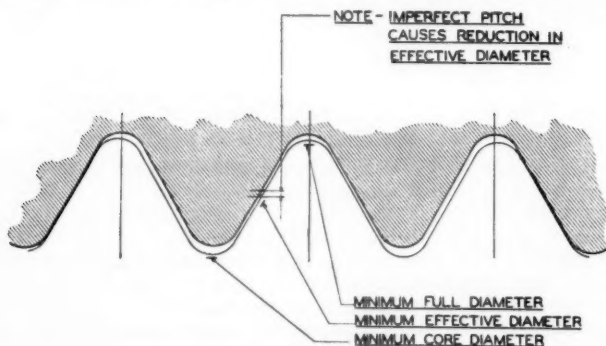


Fig. 7.—Pitch error.

the thread angle too small, and again point contact is in evidence.

Fig. 7 shows the effect of pitch error but with correct thread form. It will be noted that in order to correct a pitch error on $2\frac{1}{2}$ threads it

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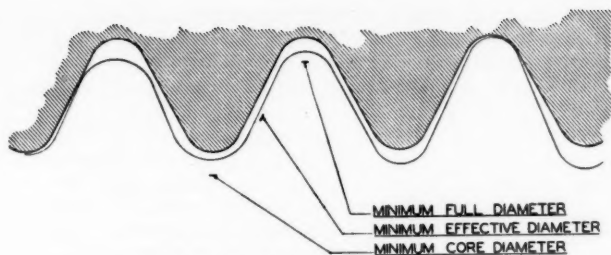


Fig. 8.—"Drunken" thread.

has been necessary to reduce the simple effective diameter to the low limit. The effect of tightening a nut on such a thread would be that the whole load would be taken on one thread, unless pressure

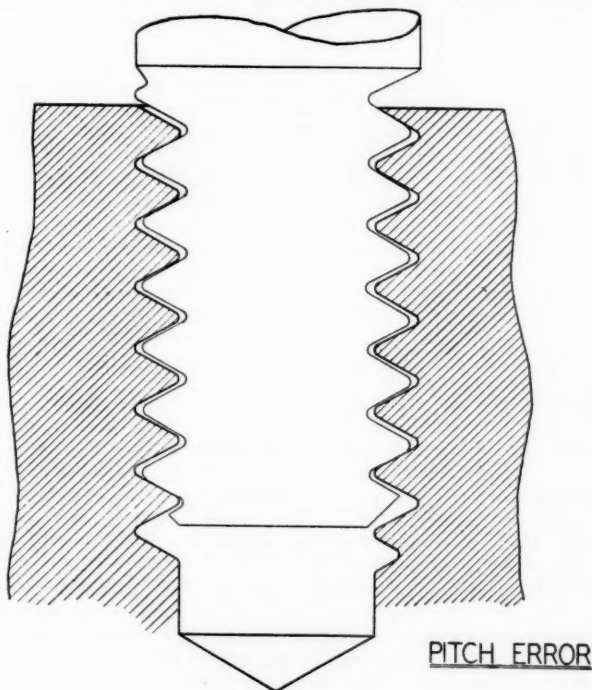


Fig. 9.

is used to such an extent as to distort the first thread until the second thread comes in contact and distortion of the first and second thread until the third is in contact and so on.

It will also be seen, from Fig. 8, that a drunken thread will give line contact.

Fig. 9 shows the effect of pitch error in a graphical manner. A stud is shown screwed into a tapped hole. When the shoulder of the screwed portion of the stud comes into contact with the ace of the threaded hole the top flank of the stud takes the pressure. It will be noted that only the flank of the top thread is in contact. Were it possible to get a section of an average stud and thread after being screwed home by an average fitter or driven home on a machine it would be interesting to see the amount of distortion which normally takes place.

The example given in Fig. 10 shows a thread of correct form and accurate pitch cut to the minimum tolerance. It will be seen that in spite of the apparent slackness between this thread and the gauge,

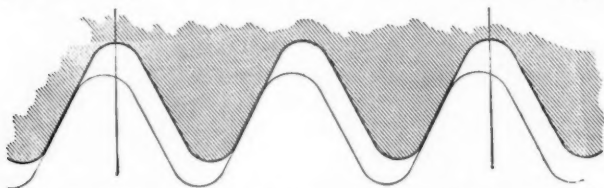


Fig. 10.—Male and female diameters on extreme limits.

there is a large proportion of flank contact. It therefore follows that providing a thread will enter a full form gauge, and the simple effective diameter is not less than the bottom limit, the more slackness there is existing between the thread and the full form gauge the more accurate is the thread.

It is, of course, possible to produce a thread almost perfect just below the top limit, but it is only possible to determine its accuracy by special inspection of its various elements, whereas the accuracy of the slack thread can be judged by the degree of slackness when using normal gauges. The foregoing examples are sufficient to denote the manner in which the thread form can vary, necessitating suitable reduction of the simple effective diameter, to enable the thread to enter a full form gauge.

Let us consider what happens when a nut is tightened on a bolt or a stud is fitted in a tapped hole. As the face of the nut makes contact or the lead of the thread on the stud makes contact, the opposing flanks of the mating threads are forced together as the nut or stud is finally tightened. The amount of contact is increased as further pressure is applied, but at the very best very little contact

is obtained, and this only at the expense of distorted threads. Such nuts or studs are liable to become loose rather easily, because the friction between the surfaces determines their capacity for holding.

Let us take as an illustration how it is possible to accept a thread with the effective diameter below the low limit by using a full form ring gauge. We have a Wickman gauge set to a tolerance of 0.0065 in. and a full form ring gauge. In addition there are two screwed plugs, one being made to the full nominal outside diameter and minus 0.007 in. effective diameter. This is a good fit in the ring gauge but is rejected by the Wickman gauge. The second screwed plug is slightly undersize on the full diameter and minus 0.006 in. on the effective diameter and appears to be a very slack fit in the ring gauge. As it will pass through the Wickman "go" anvils and will not pass the "not go" anvils it is within the desired tolerances. The fact that it is a slack fit in the ring gauge indicates that the thread does not vary materially from the theoretical size in regard to pitch and flank angle.

In order to make a direct check on the simple effective diameter various methods are in use. Special micrometers are available in which anvils are fitted for location on the flanks of the thread. A range of Vee pieces are available for insertion in the fixed end of the micrometer, each Vee covering a predetermined number of pitches. The adjustable spindle of the micrometer is shaped to the flank angle of the thread. Another method adopted is the use of two wires of suitable diameter in conjunction with a standard micrometer. The wires are held in position on the thread, one on each side, and a measurement taken over the pins with a micrometer. A certain amount of skill and familiarity is required to carry out this check satisfactorily. It was until comparatively recently considered necessary to use two wires on one side of the screw and one on the opposite side, and in unskilled hands this method is desirable.

A further method of checking the simple effective diameter is by means of wires in conjunction with a Zeiss passameter. Two wires of suitable diameter for the pitch of the thread to be checked and spaced to suit the pitch are located on the fixed spindle. A wire of similar diameter is located on the movable spindle, and is allowed to oscillate to take up its correct position as required by the helix angle of the thread. The gauge portion of this instrument is used as a comparator, and when a correct setting has been obtained it is possible to ascertain whether the size is within pre-determined limits.

Each of the methods of measuring the simple effective diameter which has been described has its own particular uses, but the most accurate check and the one in general use for gauges is carried out on a diameter measuring machine.

This consists of a small cast iron base with vee slides on which is mounted a table containing vee slides at right angles to those on the base. On this slide a bracket is mounted containing on one side a micrometer thimble of large diameter calibrated to .0001 in. On the other side is a spindle which can be adjusted to suit a wide range of diameters. On this spindle is mounted a fiducial indicator which is operated by pressure on the measuring face of the spindle. The indicator is set to zero by interposing slip gauges or a suitable block gauge of the required size, when the micrometer is set to a known position. Any variation in the micrometer reading, when the indicator is on the fixed fiducial marks denotes variation from nominal diameter. The part to be measured is mounted in adjustable centres carried on the base of the machine, and whilst the measurement is being made the slide containing the part to be checked is fully floating and free to take up a position determined by the spindle and micrometer. Pins of suitable diameter are suspended in position between the thread and the anvil, one on each side, whilst pressure is applied by the micrometer.

The pins used for effective diameter measurement are specially prepared and are identified by small metal labels which are attached to them by a ring and on which the diameter of the pin is marked. The diameter of pin required for any particular pitch can be determined by calculation as can also the diameter over the pins in position on the thread ; although it is possible to obtain a list of recommended sizes from the N.P.L. It is desirable for the pins to make contact half-way down the flanks.

The measurement of the core diameter is taken by the use of suitably shaped vee-pieces. These consist of hardened steel prisms having an angle of about 45° , with the front edge finished to a radius somewhat smaller than that of the curvature of the finest thread which it is desired to measure. It is useful to have such vees made in a series of different sizes, to cover the range of screws to be inspected. The actual sizes of the vee-pieces do not require to be known, nor do they need to be equal in size. It is essential, however, that each vee-piece should be uniform along its length, i.e., the front measuring edge must be parallel to the back face, and both must be straight. The outside diameter can also be checked on this machine. In some instances a Prestwich fluid gauge is mounted on the pressure spindle instead of the fiducial indicator. A check on the angle of the thread can be made by using a series of pins of varying diameter.

Thread form is usually checked by means of optical projection apparatus. These exist in many forms but a brief description of two will suffice to indicate their uses. The optical system consists of a carbon arc or 100 watt bunch filament lamp used in conjunction with a condenser to give an illuminating beam of parallel light, and a

SCREW THREADS

projector lens. The object to be projected is mounted on a horizontal slide either between centres or clamped in a suitable position.

The image is formed on a vertical screen about 20 ft. away and is generally 50 times full size. Focussing is carried out by fine adjustment of the position of the object in relation to the projection lens by means of cords operated at the screen. The image is compared with a standard diagram accurately drawn to the correct scale. The angle of thread can also be checked by means of a protractor suitably mounted. The chief feature of this type of projector is the large area of field, 6 ft. in diameter, over which the distortion is negligible. Plate gauges up to $1\frac{1}{2}$ in. in size can be examined as a whole.

With the projector mounted on rails running at right angles to the screen the degree of magnification can be varied. From a scale fixed alongside the rails any desired magnification can be obtained within the compass of the room.

The number of vertical projectors available is considerable and it is proposed to refer only to the Ziess toolmakers' microscope. With this type of projector the image is shown on a glass screen on which master thread forms for each pitch are available. Only one thread can be checked at a time and to bring another thread in contact with the master form the slide of the machine has to be traversed. This is very accurately made, the traverse being controlled by micrometer adjustment or by means of slip gauges so that pitch error can also be checked. The largest normal magnification is twenty times full size but by fitting an additional screen at a suitable distance behind the projector a magnification of 50 times full size can be obtained. The area of field on this projector is limited, but due to the accurate disposition of the slides in conjunction with the micrometer adjustment or by the use of slip gauges, large gauges can be inspected a section at a time.

For the purpose of checking the form and angle of internal threads it is necessary to take a cast of the thread. The most satisfactory means of making such a cast is by the use of a good quality dental wax, or plaster of paris. The pitch of a screw is checked by means of a machine originally designed by the N.P.L. The machine consists of a bed in which centres are fitted to carry the screw or gauge to be checked, a sliding bar carrying a micrometer and an indicator and saddle. By using an adaptor internal threads can also be checked.

A hardened steel gauge or stylus is adjusted to engage with the space in a thread until the indicator is opposite a fixed fiducial point. The micrometer reading which is easily read to 0.0001 in. is noted and the stylus then traversed along the screw and a reading taken in each space. When the stylus is centralised in its correct position

the indicator in each instance is opposite the fixed fiducial point. In this position the micrometer reading is taken and the amount of traverse noted from which the pitch error can be deduced.

For the commoner pitches specially graduated dials can be attached to the micrometer thimble. These dials are divided according to the whole number and fraction of a revolution of the micrometer screw necessary to move the stylus a distance equal to the nominal pitch of the screw under test. The actual error of the successive threads is then readily obtained from a fixed dial graduated to read direct to 0.0001 in. B.A. and metric threads can also be accurately checked by means of a dial fully divided into 250 parts. A number of feeler pieces having a graded series of radii are provided and a feeler piece or stylus is selected which touches about half-way down the flanks of the threads to be checked.

For checking the effective diameter of internal threads various methods are in use. For inspecting small diameter gauges a series of male gauges are made of known diameter to check the various elements. For checking the core diameter plain plug gauges are used. For the effective diameter graded gauges which have the crests and roots removed are inserted until one will just enter. The full diameter is checked by means of gauges consisting of thin threads with a suitable crest radius. The pitch and form of tooth are checked by methods already described.

Suitable machines are available for checking the effective diameter of larger diameter internal threads. One such is the Zeiss horizontal optimeter. A stylus with a suitable ball end for the pitch to be measured is used on diametrically opposite sides of the thread. These are first set to suitable blocks containing vee slots. The two setting blocks are stepped in relation to each other an amount equal to half the pitch and also set apart an amount which will give the correct effective diameter setting when the ball points are located in the vee slots. This setting is then used as a basis measurement and any deviation in the setting when the ball points are located in the thread denotes the amount of error. Various types of location are used and become more robust as the diameter of the thread to be measured increases.

This subject of screw threads is very extensive and it is not possible to deal with it in any other than a general way in a paper such as this. It is hoped, however, that sufficient has been said to arouse your interest in this very important subject. In conclusion, I wish to acknowledge the loan of slides by the Bristol Aeroplane Co. Ltd., and Mr. S. J. Harley of The Coventry Gauge & Tool Co. Ltd., and the loan of the Wickman gauge and ring gauge and examples of screwed parts by Messrs. Alfred Herbert, Ltd.

Discussion.

MR. DAUNCEY : We have all been interested in what Mr. Kenworthy has told us to-night, but we are sorry that he has not touched upon the manufacturing side of screw threads, which I think is one of the biggest problems, to get them to agree with the elaborate gauge system which he has described, and in use to-day. We should very much like to have some of his ideas on machining threads on various materials, particularly duralumin and stainless steel. We have found considerable difficulty with dies on duralumin. We use the Coventry diehead and dies and they screw the threads quite well, but the dies do not seem to stand up to the work. We also have difficulty in screwing up to the shoulder to the limits allowed by the authorities. Another difficulty is to machine a thread on stainless steel. With regard to the development of ground threads, I should like to know why it is thought advisable to grind threads. I appreciate the necessity for having a perfect fit in some instances. Would he recommend it for commercial work—the better class work and aircraft work—and is there all that practical difference and advantage in having ground threads?

MR. KENWORTHY : I dealt with the manufacturing side in regard to its development, but did not go into details, as time did not permit. I cannot offer Mr. Dauncey any help in regard to screwing duralumin with dies. He states that he has a Coventry die-head, and if he is using the dies recommended by the manufacturer of the die-head he has some of the best equipment available of this type. It is not generally known, however, that threads can be produced on non-ferrous metals by grinding, and with a suitable grinding wheel excellent results can be obtained. It is also possible to produce threads to a shoulder within the amount generally recognised for an undercut. For producing threads on stainless steel, thread grinding is ideal. It is generally assumed that thread grinding is expensive, but on quantity production on metals which give difficulty on die-head production it is often cheaper to grind, while the results are very much more satisfactory in regard to finish. Grinding of threads has not developed purely from the point of view of accuracy, but chiefly due to the difficulty in producing satisfactory threads on alloy steels with the die-heads.

MR. DANIELS : May I ask whether in the grinding of stainless steel the wheels become clogged? It is such tough stuff I should think it would clog the wheels.

MR. KENWORTHY : The development of thread grinding has been made possible by the enormous progress made by manufacturers of grinding wheels. Not so long ago it was considered unnecessary

to use wheels with a grit higher than 90. A peculiar characteristic of the wheels used for grinding threads is that the grits range from 90 to 200. In this range wheels can be found that will produce threads on stainless steel for long periods with good results, without re-dressing and with no signs of clogging. An instance occurred a few days ago where a visitor was anxious to see threads being ground. He stopped by a machine on which threads were being ground on a very tough alloy steel and asked the operator how often he had to dress the wheel. The operator replied that he did not know when it was dressed last, but thought his night-shift mate had done so during the previous week. A stud which he then produced was taken to the standard room and projected and inspected for size. The thread was almost perfect in form, and it was well within the limits of the B.S.I. standard.

MR. JOHNSON : I am in the drawing office and, therefore, the production of gauges and threads does not come directly within my province. Listening to the lecturer it seems to me that it is easier to check male threads than female threads, particularly on very small sizes, and further I cannot see that you can accurately check a small ring thread gauge. I should imagine the larger ones are quite easy, but with the smaller sizes, say $\frac{3}{16}$ in. Whitworth, it is more difficult. What is the smallest size of internal thread which can be checked by instruments ?

MR. KENWORTHY : It is only possible to check very small ring gauges by dealing with each element in turn. To check the effective diameter, two graded plug gauges, to the high and low limits respectively as specified by N.P.L., are used ; these are truncated and recessed. A full form gauge to the low N.P.L. limit checks the full form. A gauge with thin threads, with the correct crest radius, and with the outside diameter to the high limit is used as a "no go" gauge ; and finally plain "go" and "no go" plug gauges check the core. Gauges of $\frac{1}{4}$ in. and over can be checked for form by making plaster casts and direct measurement of the various elements.

MR. DANIELS : How do they take a cast on the internal threads ? How in the world can they take an accurate plaster or wax impression and get a full form thread in a $\frac{1}{4}$ in. hole ? And how do they remove it ?

MR. KENWORTHY : It is difficult to take a plaster cast in the smaller sizes, but with care it can be done satisfactorily. The gauge is placed on edge between two parallel strips, the strips covering about half the hole. About one fourth of the diameter is filled with the cast. For small gauges dental wax is used, and for larger gauges plaster of paris. The threads must be scrupulously clean, and should be smeared with a very thin and uniform mixture of petrol and vaseline to facilitate removal of the cast.

SCREW THREADS

MR. BLAKE : With regard to grinding threads, do you grind from the solid or rough it out and grind afterwards ?

MR. KENWORTHY : Threads are ground from the solid. It is usual, however, to use two cuts either on the same machine or on adjacent machines. Using adjacent machines with a number of carriers saves a considerable amount of time in setting during the second operation.

MR. BIRCH : In your lecture you spoke of full form relief. When cutting nickel steel and high-silicon aluminium alloy, does the normal difference of full form relief on ground thread taps apply ? The taps in small sizes seem to show a tendency to tear when reversed within a jig.

MR. KENWORTHY : I should say the the relieved tap will give the best results whatever the size, particularly on alloy steels and non-ferrous metals.

MR. JOHNSON : Cannot that question of tearing be solved by a suitable lubricant ?

MR. KENWORTHY : Cutting lubricant is a very important factor on alloy steels and non-ferrous metals. This has been proved conclusively in the grinding of threads, and no doubt applies also to other operations.

MR. DAUNCEY : We are particularly interested at the moment in screw gauges, and owing to the difficulty in obtaining reasonable delivery of a Wickman or caliper type of screw gauge, would you recommend the use of micrometer gauges for production work, or would you only use them for inspection ?

MR. KENWORTHY : The thread micrometer is not suitable for inspection of threads on production. It measures the simple effective diameter only, and it is known that a thread must be reduced below nominal size to ensure that it will enter a full form gauge of nominal size.

MR. MAURICE : You mentioned it was the usual practice to grind threads from the solid. Is it not better practice, when grinding thread-gauges with a single ribbed wheel, to rough out the thread first on a centre lathe ?

MR. KENWORTHY : Yes, a single wheel is never used to grind from the solid. In cases where the single wheel is used to grind gauges, the gauges are roughed out to nearly finished size prior to heat treatment and are finished by grinding. In cases where the multiple ribbed grinding wheel is used for gauge manufacture, the threads are rough ground prior to heat treatment.

MR. DANIELS : How do they grind the very small internal gauges ?

MR. KENWORTHY : It is not possible to grind small internal gauges. The threads in this case are finished very accurately prior to heat treatment, small allowances being made for distortion. The threads are then finished by lapping.

MR. BURGOINE : What is the smallest thread you have ever seen ? I once saw a thread .010 in. diameter and 100 threads to the inch. Cut on aluminium tube in quantities at that !

MR. MAURICE : I have seen a thread one millimetre diameter and 101 threads to the inch, cut with a Coventry die-head. This is a fact, and I am not saying it just to go one better than the previous speaker ! As regards pitch measurement of screws, the machine you described for doing this work appeared to take up a large amount of floor space. Is it not possible to measure pitch on the Zeiss tool-maker's microscope ?

MR. KENWORTHY : Yes, the pitch can be measured. One thread is projected on the frosted glass screen, and the micrometer measurement of the position of the slide is recorded. The next thread or any other thread is then moved along to the master outline, and the movement of the slide is again recorded. Any variation from the nominal required movement denotes the pitch error for the number of threads in question.

FOREMANSHIP

Paper presented to the Institution, Luton, Bedford and District Section, by B. C. Jenkins, M.I.P.E., Section President.

THE author in the following paper does not even pretend to put forward a basis for foremanship training but has tried to give some idea of some of the important phases of that function.

It is rather surprising to hear the widely divergent views which are expressed as to the importance and relationship of the foreman to the modern production organisation. It is argued that it is unnecessary to use men of the high calibre needed under the older conditions—that modern methods of production control have taken away the responsibility of the foreman to such an extent as to enable men of a lower order of intelligence and training to fill such positions. The author holds the opposite view and would suggest that at no time in industrial history was foremanship of a high character and calling for a higher grade of intelligence and training more vital to the success of the organisation than it is to-day.

In the earlier times of industrial units of a smaller and more compact character, more often than not run under the personal supervision of the owner and his sons, the foreman was able to fall back on the owner for both moral and material support when faced with serious difficulties. The owner, with his keen personal knowledge of the product and the processes necessary for its fabrication, often a highly skilled workman himself, was able to give most helpful and valuable advice and was a big factor in the training of his foremen.

The modern production organisation lacks to a very great extent that personal contact and lays down fairly clearly the responsibilities of the foreman and expects him to carry out his duties in a most efficient manner within the system laid down. Analysis of any manufacturing organisation soon leads to a realisation of the importance of good and competent foremanship.

A company is formed for the production of a given article, a board of directors is elected, a site is chosen and the factory built, managerial staff is appointed and so on down the line until the factory is equipped and staffed ready for production. A policy

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has been laid down, the production designed, a sales organisation set up, all to one end and for one purpose—*production*. The policy may be right, the design of the product may be good and calculated to create a keen and consistent public demand. The sales force may be efficient and on its toes, all set for what looks like a prosperous year's business, but the most vital element is yet to come, the product is the one thing that really matters. No matter how right the policy, how good the design of the product, how efficient the tools and equipment the result depends finally on the proper interpretation of the policy by production foremen by the proper and efficient use of the men, machinery, tools, and equipment placed under their command.

Business is a team game the result of which depends upon each member of the team playing his appointed part in the right and proper manner. In business just as in any other team games the brilliant individualist has his part to play and if that part is properly played he can be an extremely valuable member of the team; if he insists upon playing an individual game without reference to and co-operation with the other members the effect can be disastrous. The correct part of the brilliant individualist is to inspire the other members of the team so that collectively they will play a better and more successful game. These remarks apply with particular emphasis to foremen generally whether they be in charge of productive groups or services such as planning, tooling, ratefixing, plant, etc. It is the results of their co-operative efforts which count in the final analysis and those results must be shown in production of the right quality and at the right cost.

The first lesson which any foreman must learn is, that however successfully and efficiently he may run his own section, department or whatever his responsibility may be called, that success is totally nullified if the complete organisation be unsuccessful. Once that lesson is learned he will appreciate that it does pay to give the other fellow a hand when he is in difficulties, that it is his business and that there is nothing clever in letting the other fellow fall down.

In sporting language, you personally may have scored a goal but if the other side scored two your team has still lost the game. Much could be written about this aspect of foremanship, but if the above remarks be taken to heart and applied in the general sense there will not be much to complain about in the relationship of the foreman to other departmental activities.

We have now reached a point where the more intimate responsibilities of the foreman require consideration—stress has been laid upon the fact that quality of product at the right price is essential to successful business activities. We must now ask what is the main factor in obtaining those results—is it machinery, equipment, tools, or man power?

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The author, whilst agreeing that results depend upon a proper combination of all those elements, is of the opinion that the man himself is the main factor. The major responsibility of the foreman is in dealing with the men or women over whom he is given control—he must realise that he is dealing with living entities, men and women with intelligence, quick to react to fair and straight dealing, also quick to resent anything which they may regard as unfair. He must also realise that just as their living depends upon them carrying out their allotted tasks to his satisfaction so his living and that of every other member of the organisation depends upon the success of their collective productive efforts.

The word foremanship really means leadership and this quality of leadership is the most valuable element to be found in the make up of the successful foreman. The first class foreman will do everything possible to ensure that his workpeople are operating under clean sanitary conditions, that his shops are properly heated, lighted and ventilated, that proper provision is made for his men to obtain adequate meals in clean and cheerful surroundings if they are unable to get to their homes. He will urge upon his employers the necessity for proper transport facilities to be made available to enable them to reach their homes or get to work in the shortest possible time. Many foremen will decline to accept such items as being their responsibility, but it is the opinion of the author that anything which tends to better the working conditions of the people under his control is the responsibility of the foreman. Better conditions mean better work and a happier and more contented set of employees.

Just realise that men and women, even ignoring the human side, are the most valuable and costly tools used in industry and then see if one can justify failure to carry out any measure which will maintain or amplify their efficiency. The foreman who neglected to see that his tools were properly housed and kept in condition or that his machines were properly maintained would be regarded as totally inefficient. Surely the same reasoning applies to the labour under his control.

Having done everything possible to see that conditions of employment have been made as good as possible, the individual employees become the foreman's next problem. Just as he must study the tools and machines he intends to use, so must he study each individual operator, everyone of whom will present a different problem, requiring keen judgment of character, if the best use is to be made of their abilities. Even tools and machinery made from the same materials and to the same drawings are found in practice to be variables. We all recognise this and select accordingly. How much more difficult, but necessary, becomes the problem of the widely

varying and complex nature of the human elements with which we are called upon to deal.

Again, many foreman will argue that the man or woman is supplied to them for a specific purpose to operate a given machine or carry out a given task for which they have been trained and which they have contracted to do when accepting employment. Failure to carry out the contract efficiently results in the employee being discharged. In other cases operators are allowed to continue to carry on tasks for which they are unsuitable for lack of attention and study of their possibilities. The foreman who knows his job will study every individual over whom he has control with a view to utilising whatever talent is available in the best possible manner. This phase of a foreman's job is by no means easy and mistakes will be made even by the most competent men with long experience in handling labour. It is just as well to remember that we learn far more from our mistakes than from our successes.

One big mistake which is often made is to keep men to one job because they are particularly efficient at it and to move them is to risk loss of efficiency in that particular activity. A man who is particularly efficient on one job is quite likely to be more efficient still on another job which is a step higher up the ladder. If he is passed over when opportunity arises for promotion he will resent it and either find another berth or, if he remains, will tend to become a dissatisfied workman. Efficiency and dissatisfaction are rather poor bed fellows and efficiency soon suffers when such circumstances arise. Another serious aspect is the way in which dissatisfaction spreads. It is almost like a malignant cancerous growth eating its way in silence into the vitals of the organisation until it ends in a totally unexpected eruption which may have far reaching consequences.

The maintenance of discipline is another major problem which has to be faced and it must be realised that the discipline of the army sergeant major type pays no dividends in industrial life. That type of discipline is only applicable to such activities as lend themselves to regimentation and automatic and unreasoning obedience to orders. The different types to be found in the average factory do not react in that manner and the harsh and unreasonable shop disciplinarian will never get the best results from his men. Many young foremen who have just been promoted from the ranks make the very serious mistake of using their knowledge of the little foibles and weaknesses of the men in the shop gained whilst they were working among them. No greater mistake can never be made than taking advantage of such knowledge. Remember, your old mates are fully aware of your knowledge and respect the foreman who refuses to take advantage of it except upon those occasions when the offender is caught out in the ordinary course of the day's work.

A little firm handling and a bit of quiet advice will gain the respect of the man concerned and the men can be welded into a loyal and conscientious crew.

The competent foreman will realise that, like Nelson, he must at times have a blind eye, but he will also realise that when dealing with his men over any breach of discipline he must be tactful but firm. No two men can be dealt with in exactly the same manner. With one, the mere knowledge that he has been caught playing the fool is quite enough and a quiet glance to let him know he has been caught will do all that is necessary. Another may react quite well to a little advice given in a quiet manner. A minority will require more drastic treatment, but it should be possible in the majority of cases to leave the man feeling very little sense of resentment. The foreman who has properly studied his men will be able to deal with all breaches of discipline without sacrificing the respect of those over whom he exercises control. One thing which must be guarded against is the making of favourites. Another is listening to tale bearing. The foreman who is guilty of these offences will very soon lose the respect of his men, and if that occurs he may just as well throw up the sponge and seek new pastures, for his efforts are doomed to failure however efficient he may be in other directions.

The discharging of men under any circumstances is, to the average man, one of the most distasteful things in life. Obviously, when work falls off such happenings cannot be avoided, but the discharge of men for other reasons should never be lightly undertaken. If the man has been in the employ of the firm for any period of time and has given satisfaction during the major portion of that time, his discharge is really a wastage of assets of the firm. His local knowledge of the organisation, its processes and products, and the training he has received in his contact with them, is an investment which is immediately rendered valueless when he leaves your employ. When a foreman decides that he must discharge an employee he should regard it as a personal failure, for one of his functions is to make efficient use of all labour supplied. If this attitude is taken up the various types will receive greater study and consideration and the labour turnover be considerably reduced. This statement must not be taken as meaning that men must be handled with kid gloves, that inefficiency or insubordination must be tolerated or that men must not be discharged under any circumstances. It simply means that the labour must be studied with a view to each member becoming a happy and interested unit of the organisation.

Remember that the men under your control have the same little domestic troubles which we all suffer from at times. There may be sickness at home, or some little financial trouble—it may even be a hang over from the night before. The signs will be there to be

read and a few cheery words, perhaps a little advice, may make all the difference and avoid that little outburst which may end up in the loss of an otherwise valuable employee. Much more could be written about this human side of foremanship if time permitted, but we must move on to consideration of those other tools of industry, machines. Under modern production conditions the machine is continuously taking a more and more important part and gradually making obsolete and unnecessary much of the hand finishing which existed before machinery reached the present high state of efficiency and precision.

The degree of control over machine tools placed in the hands of the foreman is widely variable. The selection and utilisation of machinery in the large production factories is dealt with by the planning side of the organisation, the foreman only being called upon to see that the machines are efficiently used on production of the work routed to them. This method is undoubtedly the best and most efficient way of utilising machinery to the greatest advantage.

Greater responsibility in this direction is placed upon the foreman employed in the smaller production units, in the general engineering factory and in tool rooms and die shops. The author does not propose to go into methods of machine utilisation, or the merits or de-merits of any particular system, but would confine his remarks to certain elements which arise under the various systems and where foremanship can be of great assistance.

In those factories controlled by a planning department which selects machinery and allots to it a given task, there is a distinct tendency on the part of foremen to take everything for granted and regard their responsibility as merely seeing that the machines are properly operated on production of the parts allotted to each individual machine. In many cases planning departments are regarded as homes of rest peopled by individuals who imagine they know all there is to know about everything whilst in fact they know nothing about anything.

Planning department staffs consist of people who have specialised in various activities relative to production and the very nature of their work makes them realise their own limitations at a very early moment. There is a real difference between the conditions of work in a planning department and those of people actively engaged in production. The planning man is dealing with things in the abstract whilst the production man sees things and deals with them in their concrete form. Real and sincere co-operation between the production foreman and the planning engineer is the only way in which maximum efficiency can be obtained. However carefully machine tools are selected and however knowledgeable may be the person carrying out such selection, errors will be made. The trouble

may not be a serious matter to correct but, unless such correction be made, efficiency may be seriously impaired. On the other hand machines supplied for a given job may contain features which make them applicable to other jobs giving greatly increased efficiency. It is the function of any foreman to study such points and see that information is passed back to the planning department to enable them to take appropriate action.

An aspect which seems to be sadly neglected is the maintenance of machine tools. Foremen under the stress of production pressure fail to see that those little but vital adjustments are carried out at the right time and wait either until the machine breaks down, or alternatively until it is so badly worn out of adjustment that accurate production cannot be obtained even by the most skilled operator. Such neglect causes damage of a most costly nature and turns what should have represented a few hour's work into weeks, sometimes months. But that is only one side of the picture, for during the period that the machine was out of adjustment work of poor quality was being produced, probably at a higher cost in man hours than for accurate work under proper conditions of adjustment and repair.

Another angle of the same problem lies in the affect on the morale of operators when called upon to use machinery which is in a poor state of repair. How can one expect any operator to take pride in doing a good job of work if he is called upon to use an old creak?

One of the most pleasing sights is to go into one of the general engineering factories where machines are being run by mechanics of the old school under the control of a foreman who insists that his plant is properly maintained. See some of the machines of venerable age and note the way in which the operator has done his share in keeping the machine spick and span and free from damage. In contrast, it is most distressing to see the way in which highly expensive plant often has been neglected and damaged in other factories.

If the foreman does his share and sets the example to his operators by insisting upon his machines being kept in a proper state of cleanliness, adjustment, and repair, it becomes a much easier matter to get operators to take pride in doing their share in the same direction. Operators should be trained to report to their foreman any item which requires adjustment and repair and should be made to appreciate that they will be held responsible for damage caused by carelessness and lack of thought.

Talking of machinery brings us in the natural sequence to tools and the realisation that, after all, machines are in effect tool carriers, or, shall we say, tool users. The efficiency of the machine is the efficiency of the tools used therein.

It is amazing to find that machinery purchased at a high cost will often be operated with totally inefficient tools of poor quality

or, alternatively, with tools which are improperly maintained. This is another aspect in which the foreman is more important than the planning engineer or the buyer responsible for tool purchases. He is the man who is in the best position to judge the efficiency of the tools supplied for use on his machinery, whether it be from the design or quality point of view. He must also accept the responsibility for insisting that all dies, jigs, tools, and gauges are properly maintained.

Operators must be trained to realise that tools should be ground or re-conditioned at regular intervals, and that a check should be kept on the number of pieces produced between grinds to enable them to avoid damage due to over usage or excessive amounts to be removed from tools during grinding. If any production foreman will take the trouble to examine all tools returned to stores or tool room for grinding during any one day's run he will soon realise what a fruitful field for investigation and training lies in that direction. One serious aspect of this trouble which is very rarely realised, as its effect does not show up until much later in the production stage, is the cold working of materials which may possibly be set up due to using dull or worn tools.

Probably the best instance of this, which comes to the mind of the author, is the hobbing of gear teeth. Here you have a component upon which a small fortune is spent in obtaining the most accurate product possible in the green or soft state and yet after heat treatment you can get the most incomprehensible results. Heat treatment is blamed, and correctly so, inasmuch as the movement has occurred during that process, but the real criminal is often the cold working which has occurred during the hobbing process. What is the use of purchasing expensive gear shaving machines and equipment to give results within a margin of error of .0002 in. if you have already stressed and deflected the teeth to a much greater amount due to using dull tools? Much of the loss of shape and inaccuracy of relationship in machined components which have not been heat treated is due to the same cause. Breakage, excessive wear, and consequent shortening of life of tools must be the result of such maltreatment.

Foremen should ascertain the cost of the tools used under their supervision, as tool usage is one of the heaviest items which go to make up their overhead charges. That brings up another aspect of good foremanship. Most of us watch very carefully the large individual items of expenditure. For instance, if the crown of a press is pushed off or a crank broken, we realise it to be a serious matter and act accordingly, but a leaking can which is dribbling lubricating oil into the pan of a machine or possibly on to the shop floor gets scant attention. If a 2 in. drill gets broken we want to know how

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and why, but a $\frac{1}{8}$ in. drill breakage will be practically ignored. In other words the small losses pass practically unnoticed.

A good way of getting the right slant on this question is to change a pound note when you are out shopping. You apparently buy nothing of particular importance but, somehow or other, the note has dissolved. It is the host of little things which runs away with the money. The same thing applies in our everyday business life. If we can cut down the small wastages an immense lot of money will be saved. Those savings invested in better plant, better tools, better working conditions, will lead to a better competitive position in the market and will not only enable your company to pay bigger dividends but must inevitably give more consistent employment and a bigger pay packet. Need one question whether this comes within the province of good foremanship? Don't forget that no other member of the organisation is in the same position to control these items as is the foreman. A word of warning is necessary, as it is easy to make mistakes which, whilst apparently saving money, are actually adding cost. For instance, don't insist that there is still life left in that stub end of a drill and refuse to give an order for a new one. Make sure that the web is not too thick or the lands too wide or the tool too soft to work efficiently. It may be possible to salvage the tool for some other purpose but be sure that the cost of salvage is not greater than the productive value of the salvaged tool.

Don't insist upon getting further work out of the tap with about three or four threads left upon it or that set of chasers in the same condition it will require an artist to use either without creating bad errors in the job. Perhaps that reamer is only .001 in. undersize and it seems a shame to scrap it, but it will cost more to hand-ream the parts produced than the reamer is worth.

Don't use a high speed tool when a carbide tipped tool is specified. The difference in cost is large but the value of the machine hours lost will more than offset the saving in tool cost.

Don't refuse to issue orders for replacement tools to the point where your stock of tools in circulation is so low that your operators are kept waiting whilst tools are ground or that the tool room grinder has to set up to grind one tool. These mistakes and a thousand and one others are often made in the name of economy. No shop can be efficiently run without ample supplies of good tools properly maintained, but everyone must be made to realise that in dealing with tools they are handling big money, even if it does happen to be packed in small packets.

A paper of this description does not call for a full discussion of organisation, as obviously each and every foreman will have a different problem according to the type of factory and the managerial policy adopted. At the same time there are many points of similarity

in all jobs of foremanship which are worthy of discussion. The first is the necessity for planned action in all things, whether it be utilisation of men, tools, machinery, or materials. Whether the foreman be employed in a highly organised production factory in the production line, a small general engineering factory, or controlling a tool room, he will still find a thousand and one things of an organising nature left for him to carry out on his own initiative.

Only too often these details are left for minute to minute decisions of what may be termed a snap character. The good foreman will, whenever possible, plan ahead in such a manner that such decisions are limited to those emergency items which cannot be foreseen.

Material will be available when required and will be stored in an orderly manner as closely adjacent as possible to the point of usage. The next job for each operative will be chosen before he finishes his other task, so avoiding those irksome and costly waiting periods, whilst the foreman has a look round, which occur when planning ahead is not practised. Availability of tools will be checked. Observance of safety precautions will be insisted upon. Machines will be regularly lubricated. Shops will be kept clean and swarf will be removed from machines with a minimum loss of machine time. Work will be progressed through the shops to a planned schedule and the position of all work will be known, and completion dates and times be set and maintained with a reasonable degree of accuracy.

Summarised, the conclusions reached are that the first class foreman must be a man of good character, tactful, considerate, able to get and hold the respect of the labour which he is called upon to control. He must have both technical and practical ability and he able and willing to pass on his knowledge to his subordinates. He must be willing to co-operate with other members of the organisation in all matters and be able to express himself in a facile manner both verbally and in writing. He must have the courage to express his convictions even in the face of strenuous opposition. He must be prepared to carry responsibility and also to delegate authority, must be something of a psychologist able to judge and get the best from human nature. He must have a good working knowledge of the economics of manufacture, not only as bearing on his limited responsibility but on the whole organisation. He must be a good organiser with a keen and enthusiastic interest in the welfare of the firm and its employees generally. But above all, he must be a good leader of the right type.

